Design Example Report

Title	***40 W Power Supply Using TOP256EN***
Specification	90 – 265 VAC Input; 5 V, 2.0 A and 15 V, 2.0 A Outputs
Application	LCD Monitor
Author	Applications Engineering Department
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Date	October 13, 2008
Revision	1.0

Summary and Features

- Low cost, low component count, high efficiency
  - Delivers 40 W at 50 °C ambient
  - Meets output cross regulation requirements without linear regulators
- EcoSmart® – meets requirements for low no-load and standby power consumption
  - 0.05 W output power for < 0.3 W input at 265 VAC
  - No-load power consumption <200 mW at 265 VAC
  - >80% full load efficiency
- Integrated safety/reliability features:
  - Accurate, auto-recovering, thermal shutdown function maintains safe PCB temperatures under all conditions
  - Auto-restart protects against output short circuits and open feedback loops
  - Output Overvoltage protection (OVP) configurable for latching / hysteretic shutdown
  - Input undervoltage (UV) prevents power up / power down output glitches
- Meets EN55022 and CISPR-22 Class B conducted EMI with >6 dB margin

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Important Note:
Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

1 Introduction

This engineering report describes an LCD Monitor power supply utilizing the TOPSwitch®-HX TOP256EN from Power Integrations® Inc.

This report contains the power supply specifications, schematic, bill of materials, transformer documentation, printed circuit board layout, and performance data for this evaluation platform.

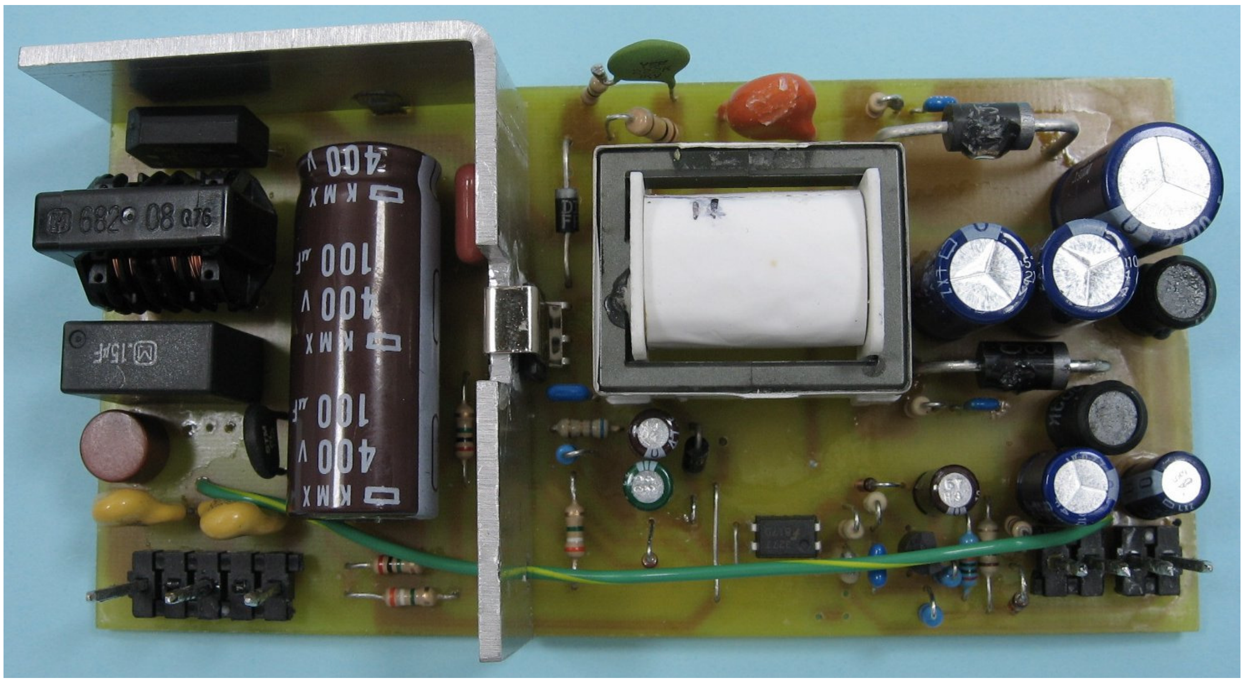

Figure 1 – Populated Circuit Board Photograph.

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2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)				0.2	W	
Output						
Output Voltage 1	V_{OUT1}	4.75	5	5.25	V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			50	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}		2.0		A	
Output Voltage 2	V_{OUT2}	12	15	18	V	± 20%
Output Ripple Voltage 2	$V_{RIPPLE2}$			150	mV	20 MHz bandwidth
Output Current 2	I_{OUT2}		2.0		A	
Total Output Power						
Continuous Output Power	P_{OUT}		40		W	
Efficiency						
Full Load	η	80			%	Measured at P_{OUT} 25 °C
Standby Input Power				300	mW	5 V @ 10 mA, Vin at 230 VAC
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B Designed to meet IEC950, UL1950 Class II				
Ambient Temperature	T_{AMB}	0		50	°C	Free convection, sea level

3 Schematic

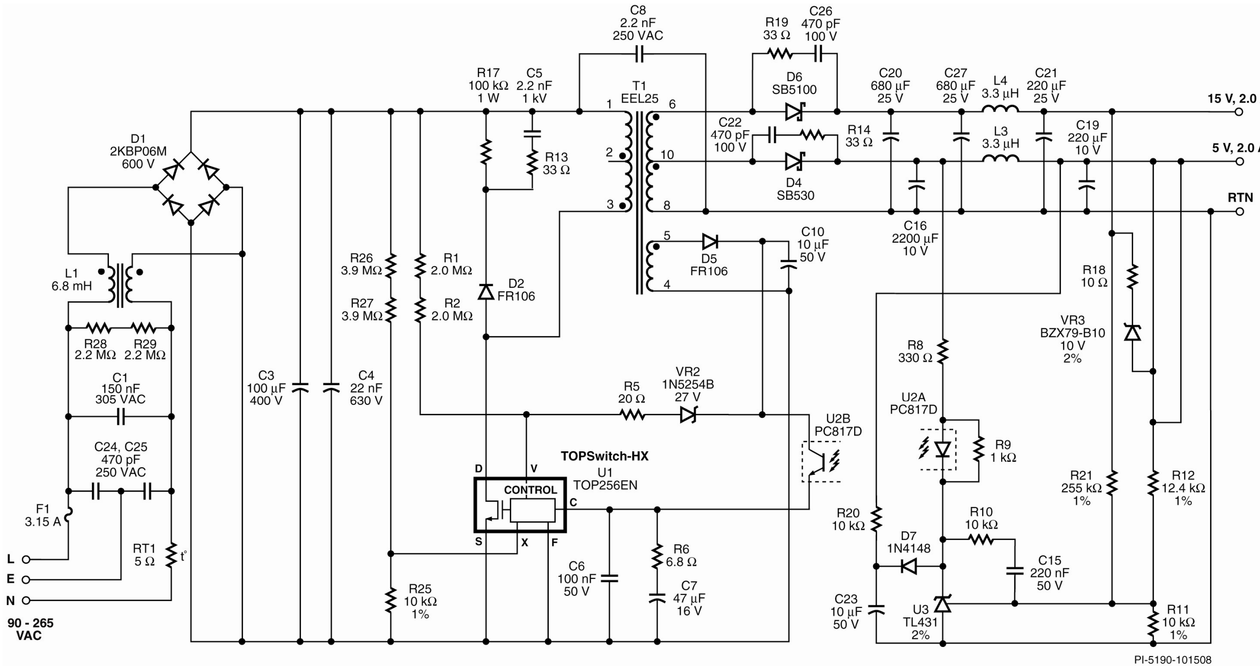

Figure 2 – Schematic.

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4 Circuit Description

This flyback converter configuration, built around the TOP256EN (U1), provides two output voltages; a 5 V output and a 15 V output. Each delivers a load current of 2.0 A. This power supply operates using inputs between 90 VAC and 264 VAC. The main output, 5 V, is regulated using voltage reference U3. A small portion of the feedback signal is also derived from the 15 V output.

4.1 Input EMI Filtering

The three-wire AC supply connects to the circuit via connector J1. Fuse F1 provides protection against catastrophic circuit faults and effectively isolates the circuit from the AC source. Thermistor RT1 limits inrush current drawn by the circuit when the AC input is first applied. Y-capacitors C24 and C25, connected from line and neutral to earth ground, reduce common-mode EMI.

X-capacitor C1 reduces differential-mode EMI. Common-mode inductor L1 prevents the coupling of common-mode EMI back to the AC source.

Bridge rectifier D1 rectifies the incoming AC to DC, and capacitor C3 filters the resulting DC. Decoupling capacitor C4, connected across the DC supply, is located physically close to the high-frequency switching circuit to reduce differential-mode EMI.

4.2 TOPSwitch Primary

Resistors R1 and R2 provide a sense current to U1 proportional to the DC voltage across capacitor C3. At approximately 100 V DC, the current through these resistors exceeds 25 µA. Once this current exceeds 25 µA switching is enabled the power supply starts up.

An RCD clamp network (D2, R13, R17, and C5) limits the drain voltage of U1 to below 700 V after the MOSFET inside U1 turns OFF.

Diode D5 rectifies the bias winding output of transformer T1, and C10 filters it. This provides the necessary bias for the optocoupler U2B.

The secondary-side feedback circuitry maintains output voltage regulation through U2. A change in current to the optocoupler diode causes a change in the current out of the optocoupler transistor (which is proportional to the CTR of the optocoupler) and into U1's C pin. The current into the C pin changes the duty cycle of switching thereby regulating the output voltage.

Zener diode VR2 and R5 provide output over-voltage protection. Any fault condition which causes the power supply output to exceed regulation limits also causes the voltage across the bias winding to increase. Consequently, Zener diode VR2 breaks down and sufficient current flows into the V pin of U1 to initiate a latching OVP. Resistor R5 limits the current into the V pin. The level of current determines whether the shutdown is latching or self-recovering.

4.3 Output Rectification

Diode D4 provides rectification for the 5 V output, and low-ESR capacitor C16 provides filtering. The low ESR of C16 ensures an acceptable level of high frequency ripple voltage on the 5 V output. The second-stage filter formed by L3 and C19 attenuates switching noise across C16.

Similarly, diode D6 rectifies the 15 V output. Low-ESR capacitors C20 and C27 provide filtering. The second-stage filter formed by inductor L4 and capacitor C21 significantly attenuates switching noise across C20 and C27.

Snubber networks comprised of R14 and C22, and R19 and C26 damp oscillations on D4 and D6 caused by transformer winding leakage inductance, reducing radiated EMI.

4.4 Output Feedback

The output voltage is controlled using shunt regulator U3. Diode D7, capacitor C23, and resistor R20 form a soft-finish circuit. Initially capacitor C23 is discharged. Increasing output voltage causes current to flow through the diode in U2A and diode D7; and C23 builds charge. The current into U2A affects current flow out of U2B and provides feedback to the primary-side circuit. Current through U2A gradually decreases as C23 becomes charged and U3 becomes operational. This ensures a gradual increase in the output voltage, which settles to its final value without overshoot. Diode D7 ensures capacitor C23 stays charged after startup. This effectively isolates C23 from the feedback circuit after startup, which discharges only when the supply shuts down. Resistor R20 provides a discharge path for C23 after the power supply is shut down.

Resistors R11, R12 and R21 form a summing regulation circuit. Resistors R12 and R21 provide feedback from the 5 V and 15 V outputs, respectively. Resistors R21 and R12 are sized such that approximately 20% of the total feedback is derived from the 15 V output, and the remainder (80%) is derived from the 5 V output.

Resistor R10 and capacitor C15 set the frequency response of the feedback circuit to achieve stable power supply operation.

Resistor R9 provides the bias current required by U3. Placing R9 in parallel with U2A ensures the bias current to U3 does not become part of the feedback current flowing through U2A. Resistor R8 sets the overall loop gain and limits current through U2A during transient conditions.

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Resistor R18 and Zener diode VR3 improve cross-regulation when only the 5 V output is loaded, since this situation causes the 15 V output to operate at the higher end of the specification.

5 PCB Layout

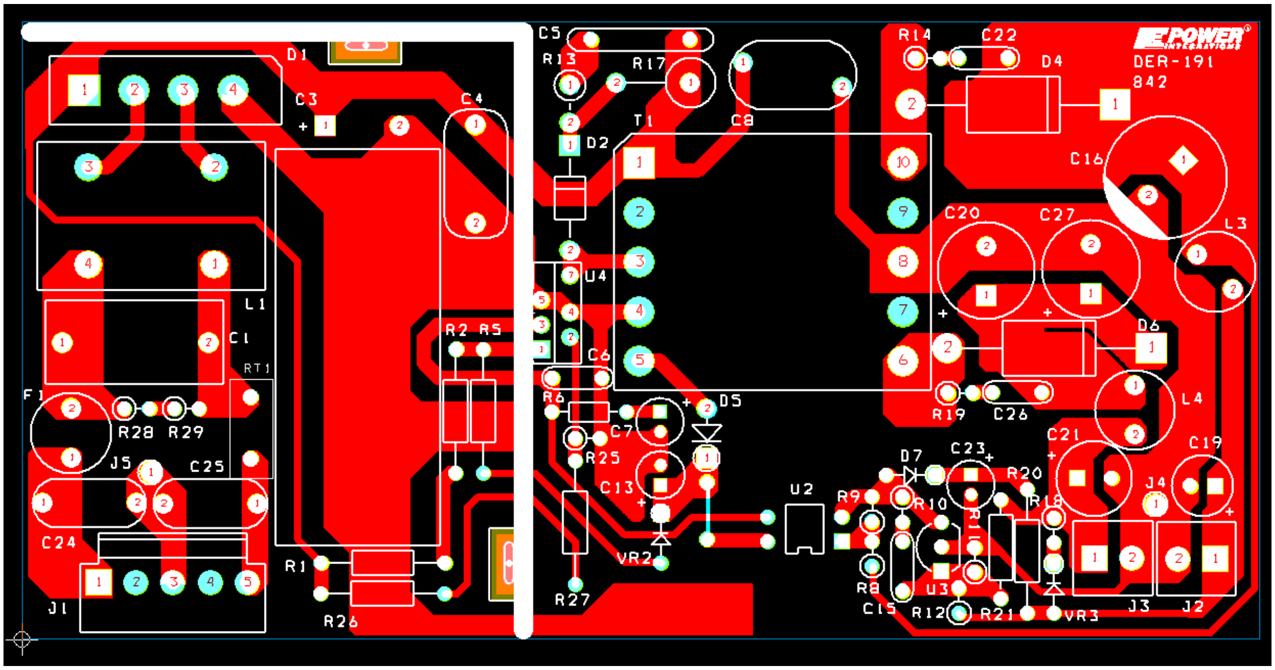

Figure 3 – Printed Circuit Layout.

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6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	C1	150 nF, 305 VAC, X2	B32922A2104M	Epcos
2	1	C3	100 µF, 400 V, Electrolytic, Low ESR, 630 mΩ, (16 x 40)	EKMX401ELL101ML40S	Nippon Chemi-Con
3	1	C4	22 nF, 630 V, Polypropylene Film	ECW-F6223HL	Panasonic
4	1	C5	2.2 nF, 1 kV, Disc Ceramic	NCD222K1KVY5FF	NIC Components Corp
5	1	C6	100 nF, 50 V, Ceramic, Z5U, .2Lead Space	C317C104M5U5TA	Kemet
6	1	C7	47 µF, 16 V, Electrolytic, Gen. Purpose, (5 x 11)	KME16VB47RM5X11LL	Nippon Chemi-Con
7	1	C8	2.2 nF, Ceramic, Y1	440LD22-R	Vishay
8	1	C13	22 µF, 50 V, Electrolytic, Low ESR, 900 mΩ, (5 x 11.5)	ELXZ500ELL220MEB5D	Nippon Chemi-Con
9	1	C15	220 nF, 50 V, Ceramic, X7R	B37987F5224K000	Epcos
10	1	C16	2200 µF, 10 V, Electrolytic, Very Low ESR, 21 mΩ, (12.5 x 20)	EKZE100ELL222MK20S	Nippon Chemi-Con
11	1	C19	220 µF, 10 V, Electrolytic, Low ESR, 250 mΩ, (6.3 x 11.5)	ELXZ100ELL221MFB5D	Nippon Chemi-Con
12	2	C20 C27	680 uF, 25 V, Electrolytic, Very Low ESR, 23 mΩ, (10 x 20)	EKZE250ELL681MJ20S	Nippon Chemi-Con
13	1	C21	220 µF, 25 V, Electrolytic, Low ESR, 120 mΩ, (8 x 12)	ELXZ250ELL221MH12D	Nippon Chemi-Con
14	1	C22	470 pF, 100 V, Ceramic, X7R	B37981M1471M000	Epcos
15	1	C23	10 µF, 50 V, Electrolytic, Gen Purpose, (5 x 11)	ECA-1HHG100	Panasonic
16	2	C24 C25	470 pF, 250 VAC, Film, X1Y1	CD95-B2GA471KYNS	TDK
17	1	C26	470 pF, 100 V, Ceramic, COG	5NK471KOBAM	AVX Corp
18	1	D1	600 V, 2 A, Bridge Rectifier, Glass Passivated	2KBP06M	Vishay
19	2	D2 D5	800 V, 1 A, Fast Recovery Diode, 500 ns, DO-41	FR106	Diodes Inc.
20	1	D4	30 V, 5 A, Schottky, DO-201AD	SB530	Vishay
21	1	D6	100 V, 5 A, Schottky, DO-201AD1	SB5100	Fairchild
22	1	D7	75 V, 300 mA, Fast Switching, DO-35	1N4148	Vishay
23	1	F1	3.15 A, 250V,Fast, TR5	37013150410	Wickman
24	1	J1	5 Position (1 x 5) header, 0.156 pitch, Vertical	26-48-1055	Molex
25	2	J2 J3	2 Position (1 x 2) header, 0.156 pitch, Vertical	26-48-1021	Molex
26	2	J4 J5	PCB Terminal Hole, 22 AWG	N/A	N/A
27	1	L1	6.8 mH, 0.8 A, Common Mode Choke	ELF15N008	Panasonic
28	2	L3 L4	3.3 µH, 5.5 A, 8.5 x 11 mm	R622LY-3R3M	Toko
29	2	R1 R2	2.0 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-2M0	Yageo
30	1	R5	20 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-20R	Yageo
31	1	R6	6.8 Ω, 5%, 1/8 W, Carbon Film	CFR-12JB-6R8	Yageo
32	1	R8	330 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-330R	Yageo
33	1	R9	1 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-1K0	Yageo
34	2	R10 R20	10 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-10K	Yageo
35	2	R11 R25	10 kΩ, 1%, 1/4 W, Metal Film	ERO-S2PHF1002	Panasonic
36	1	R12	12.4 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-12K4	Yageo

37	3	R13 R14 R19	33 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-33R	Yageo
38	1	R17	100 kΩ, 5%, 1 W, Metal Oxide	RSF100JB-100K	Yageo
39	1	R18	10 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-10R	Yageo
40	1	R21	255 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-255K	Yageo
41	2	R26 R27	3.9 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-3M9	Yageo
42	1	RT1	TKS Thermistor, 5 Ω, 3 A	SCK08053MSY	Thinking Elect.
43	1	T1	Bobbin, EEL25, Horizontal, 10 pins	YW-236-03B	Yih-Hwa Enterprises
44	1	U2	Opto coupler, 35 V, CTR 300-600%, 4-DIP	PC817X4	Sharp
45	1	U3	2.495 V Shunt Regulator IC, 2%, 0 to 70C, TO-92	TL431CLPG	On Semiconductor
46	1	U1	TOPSwitch-HX, TOP256EN, eSIP-7C	TOP256EN	Power Integrations
47	1	VR2	27 V, 5%, 500 mW, DO-35	1N5254B	Microsemi
48	1	VR3	10 V, 500 mW, 2%, DO-35	BZX79-B10	Vishay
49	2	R28 R29	2.2 M, 5%, 1/4 W, Carbon Film	CFR-25JB-2M2	Yageo
50	2	TER MINA L	Terminal, Eyelet, Tin Plated Brass, Zierick PN 190	190	Zierick

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7 Transformer Specification

7.1 Electrical Diagram

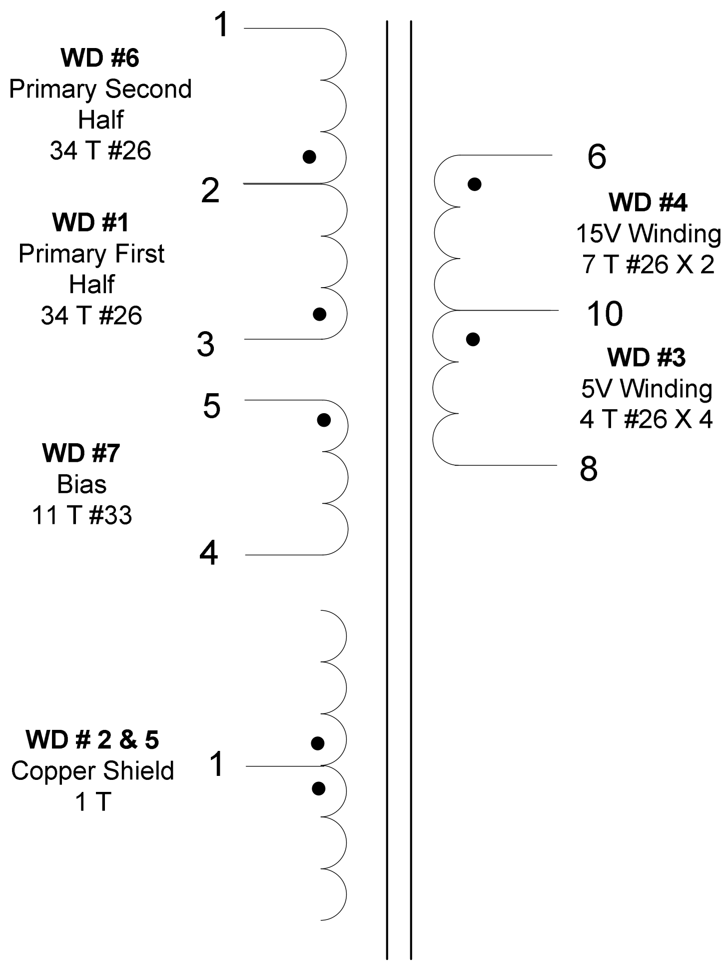

Figure 4 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pins 1-5 to Pins 6-10	3000 VAC
Primary Inductance	Pins 1-3, all other windings open, measured at 100 kHz, 0.4 VRMS	381 µH, ±10%
Resonant Frequency	Pins 1-3, all other windings open	600 kHz (Min.)
Primary Leakage Inductance	Pins 1-3, with Pins 6-10 shorted, measured at 100 kHz, 0.4 VRMS	10 µH (Max.)

7.3 Materials

Item	Description
[1]	Bobbin: EEL25, 10 pins. Core EEL 25 PC44 gapped for an ALG of 82 nH/t^2
[2]	Magnet Wire: #26 AWG, double coated
[3]	Tape: 3M Polyester Film, 2.0 mils thick, 0.645 inch wide
[4]	Tape: 3M Polyester Film, 2.0 mils thick, 0.866 inch wide
[5]	Copper Foil, 2 mils thick, 0.63 inch wide
[6]	Margin Tape: 3M 3.0 mm wide
[7]	Magnet Wire: #33 AWG
[8]	Teflon Tube
[9]	Varnish

7.4 Transformer Build Diagram

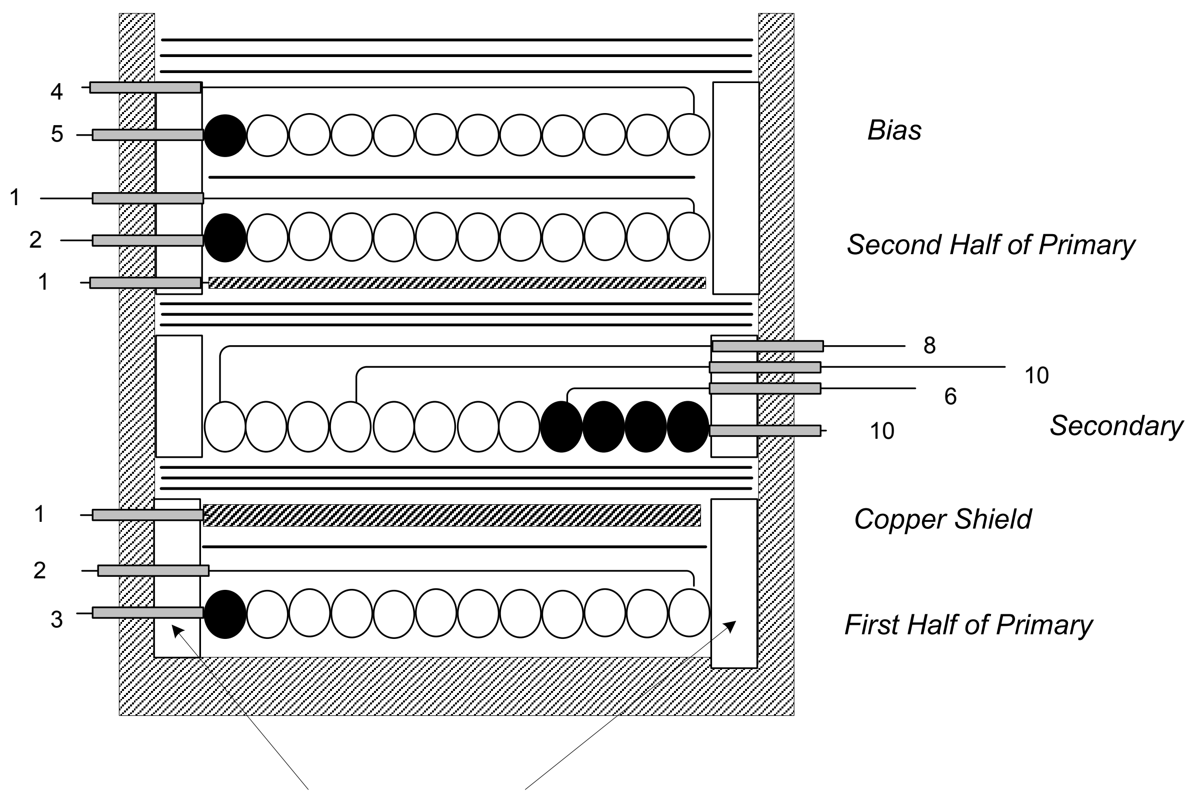

Figure 5 – Transformer Build Diagram.

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7.5 Copper Shield Preparation

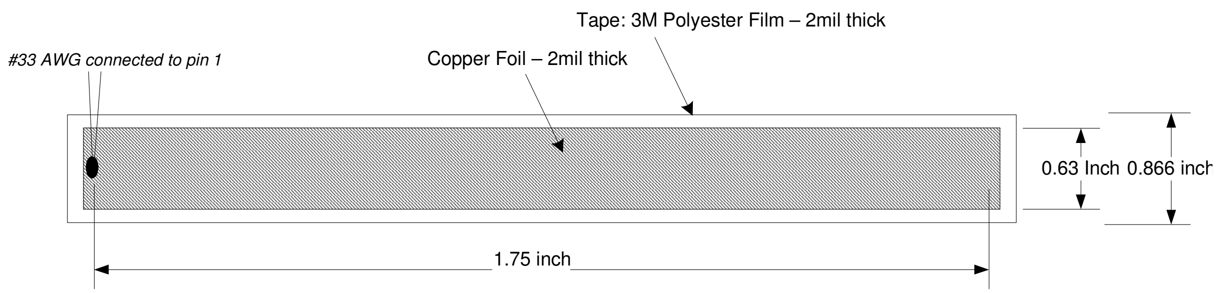

Figure 6 – Copper Shield Details - 1.

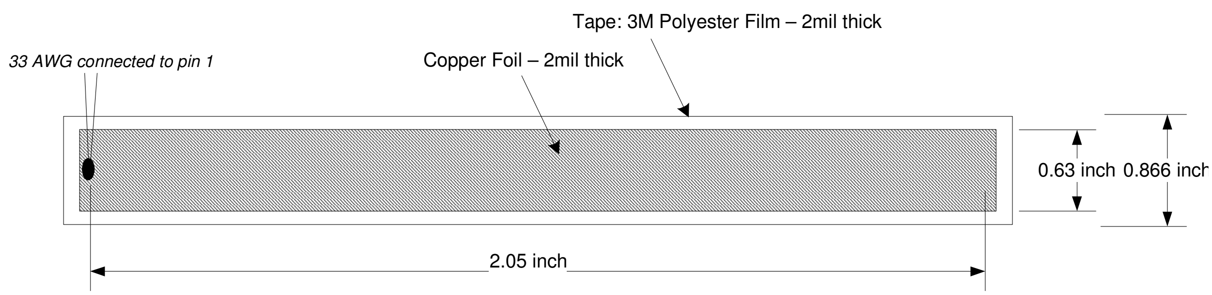

Figure 7 – Copper Shield Details - 2.

7.6 Winding Instructions

General Note	Primary side of the bobbin orients to the left hand side. Place 3.0 mm margin tape on both sides of the bobbin for all windings primary and secondary. Wind in the clockwise direction.
WD1 **1/2 Primary**	Start on pin 3, wind 34 turns of item [2] from left to right with tight tension and bring the wire across the bobbin to terminate at pin 2. Use item [8] on both start and end leads.
Insulation	1 layer of tape item [3].
WD2 **Copper Shield**	Use the pre-prepared copper shield as shown on the previous page. Connect lead to pin 1, wind 1 turn. Place tape of item [4] first to avoid shorts. Use item [8] on the lead.
Insulation	Continue to wind 3 layers of tape item [4].
Margin Tape	Place 3.0 mm margin tape on both side of the bobbin for windings 3 and 4.
WD3 **1st Secondary**	Start on pin 10, wind 4 turns of item [2], using 4 parallel wires. Wind them evenly, spread along the bobbin width. Temporarily leave the lead on left hand side. Use item [8] on both start and end leads.
WD4 **2nd Secondary**	Start on pin 6, wind 7 bifilar turns of item [2] from right to left, spread the winding evenly between previous windings, across the bobbin, and bring the wire back to the right to terminate on pin 10. Then bring previous end lead back to right hand side and terminate on pin 8. Use item [8] on both the start and end leads.
Insulation	3 layers of tape item [4].
Margin tape	Place 3.0 mm margin tape on both sides of the bobbin for winding 5 and 6.
WD5 **Copper Shield**	Use the pre-prepared copper shield as shown on the previous page. Connect the lead to pin 1, and wind 1 turn. Place tape of item [3] first to avoid shortage. Use item [8] on the lead.
WD5 **2/2 Primary**	Start on pin 2 and wind 34 turns of item [2] from left to right with tight tension. Wind with tight tension across entire bobbin width and terminate at pin 1. Use item [8] on both start and end leads.
Insulation	1 layer of tape item [3].
Bias winding **WD6**	Start at pin 5, wind 11 turns of item [7] across entire bobbin evenly. Terminate at pin 4. Use item [8] on both start and end leads.
Insulation	3 layers of tape item [4].
Varnish	Grind the core and put together. Primary inductance 381 µH. Dip varnish.

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8 Design Spreadsheet

ACDC_TOPSwitchHX_021308; Rev.1.8; Copyright Power Integrations 2008	INPUT	INFO	OUTPUT	UNIT	TOP_HX_021308: TOPSwitch-HX Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
VACMIN	85			Volts	Minimum AC Input Voltage
VACMAX	265			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	5.00			Volts	Output Voltage (main)
PO_AVG	40.00			Watts	Average Output Power
PO_PEAK			40.00	Watts	Peak Output Power
n	0.80			%/100	Efficiency Estimate
Z	0.50				Loss Allocation Factor
VB	15			Volts	Bias Voltage
tC	3.00			mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	100.0		100	uFarads	Input Filter Capacitor
ENTER TOPSWITCH-HX VARIABLES					
TOPSwitch-HX	TOP256EN			Universal / Peak	115 Doubled/230V
Chosen Device		*TOP256EN*	Power Out	86 W / 86 W	119W
KI	0.75				External Ilimit reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT)
ILIMITMIN_EXT			1.778	Amps	Use 1% resistor in setting external ILIMIT
ILIMITMAX_EXT			2.047	Amps	Use 1% resistor in setting external ILIMIT
Frequency (F)=132kHz, (H)=66kHz	F		F		Select 'H' for Half frequency - 66kHz, or 'F' for Full frequency - 132kHz
fS			132000	Hertz	TOPSwitch-HX Switching Frequency: Choose between 132 kHz and 66 kHz
fSmin			119000	Hertz	TOPSwitch-HX Minimum Switching Frequency
fSmax			145000	Hertz	TOPSwitch-HX Maximum Switching Frequency
High Line Operating Mode			FF		Full Frequency, Jitter enabled
VOR	94.00			Volts	Reflected Output Voltage
VDS			10	Volts	TOPSwitch on-state Drain to Source Voltage
VD	0.50			Volts	Output Winding Diode Forward Voltage Drop
VDB	0.70			Volts	Bias Winding Diode Forward Voltage Drop
KP	0.60				Ripple to Peak Current Ratio (0.3 < KRP < 1.0 : 1.0< KDP<6.0)
PROTECTION FEATURES					
LINE SENSING					
VUV_STARTUP			95	Volts	Minimum DC Bus Voltage at which the power supply will start-up
VOV_SHUTDOWN			445	Volts	Typical DC Bus Voltage at which power supply will shut-down (Max)
RLS			4.0	M-ohms	Use two standard, 2 M-Ohm, 5% resistors in series for line sense functionality.
OUTPUT OVERVOLTAGE					
VZ			27	Volts	Zener Diode rated voltage for Output Overvoltage shutdown protection
RZ			5.1	k-ohms	Output OVP resistor. For latching shutdown use 20 ohm resistor instead
OVERLOAD POWER LIMITING					
Overload Current Ratio at VMAX					Enter the desired margin to current limit at VMAX. A value of 1.2 indicates that the current limit should be 20% higher than peak primary current at VMAX
Overload Current Ratio at VMIN			1.13		Margin to current limit at low line.
ILIMIT_EXT_VMIN			1.50	A	Peak primary Current at VMIN
ILIMIT_EXT_VMAX			1.52	A	Peak Primary Current at VMAX
RIL			8.39	k-ohms	Current limit/Power Limiting resistor.

RPL			N/A	M-ohms	Resistor not required. Use RIL resistor only
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	Auto		EEL25		Core Type
Core	EEL25	*EEL25*		*P/N:*	PC40EE25.4/32/6.4-Z
Bobbin	EEI25	*EEL25_ BOBBIN*		*P/N:*	*
AE	0.4040		0.404	cm^2	Core Effective Cross Sectional Area
LE	7.3400		7.34	cm	Core Effective Path Length
AL	1420.0		1420	nH/T^2	Ungapped Core Effective Inductance
BW	22.3		22.3	mm	Bobbin Physical Winding Width
M	3.20			mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	2.00				Number of Primary Layers
NS	4		4		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			86	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.55		Maximum Duty Cycle (calculated at PO_PEAK)
IAVG			0.58	Amps	Average Primary Current (calculated at average output power)
IP			1.50	Amps	Peak Primary Current (calculated at Peak output power)
IR			0.90	Amps	Primary Ripple Current (calculated at average output power)
IRMS			0.80	Amps	Primary RMS Current (calculated at average output power)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			381	uHenries	Primary Inductance
LP Tolerance			10		Tolerance of Primary Inductance
NP			68		Primary Winding Number of Turns
NB			11		Bias Winding Number of Turns
ALG			82	nH/T^2	Gapped Core Effective Inductance
BM			2071	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP			3110	Gauss	Peak Flux Density (BP<4200) at ILIMITMAX and LP_MAX. Note: Recommended values for adapters and external power supplies <=3600 Gauss
BAC			621	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			2053		Relative Permeability of Ungapped Core
LG			0.59	mm	Gap Length (Lg > 0.1 mm)
BWE			31.8	mm	Effective Bobbin Width
OD			0.47	mm	Maximum Primary Wire Diameter including insulation
INS			0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.40	mm	Bare conductor diameter
AWG			27	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			203	Cmils	Bare conductor effective area in circular mils
CMA			253	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
Primary Current Density (J)				Amps/mm^2	Primary Winding Current density (3.8 < J < 9.75)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			25.63	Amps	Peak Secondary Current
ISRMS			12.37	Amps	Secondary RMS Current
IO_PEAK			8.00	Amps	Secondary Peak Output Current

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IO			8.00	Amps	Average Power Supply Output Current
IRIPPLE			9.43	Amps	Output Capacitor RMS Ripple Current
CMS			2474	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			16	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			1.29	mm	Secondary Minimum Bare Conductor Diameter
ODS			3.98	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			1.34	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN			564	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			27	Volts	Output Rectifier Maximum Peak Inverse Voltage
PIVB			78	Volts	Bias Rectifier Maximum Peak Inverse Voltage
TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)					
1st output					
VO1	5.00		5	Volts	Output Voltage
IO1_AVG	2.00		2.00	Amps	Average DC Output Current
PO1_AVG			10.00	Watts	Average Output Power
VD1			0.5	Volts	Output Diode Forward Voltage Drop
NS1			4.00		Output Winding Number of Turns
ISRMS1			3.092	Amps	Output Winding RMS Current
IRIPPLE1			2.36	Amps	Output Capacitor RMS Ripple Current
PIVS1			27	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS1			618	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS1			22	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS1			0.65	mm	Minimum Bare Conductor Diameter
ODS1			3.98	mm	Maximum Outside Diameter for Triple Insulated Wire
2nd output					
VO2	15.00			Volts	Output Voltage
IO2_AVG	2.00			Amps	Average DC Output Current
PO2_AVG			30.00	Watts	Average Output Power
VD2			0.7	Volts	Output Diode Forward Voltage Drop
NS2			11.42		Output Winding Number of Turns
ISRMS2			3.092	Amps	Output Winding RMS Current
IRIPPLE2			2.36	Amps	Output Capacitor RMS Ripple Current
PIVS2			78	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS2			618	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS2			22	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS2			0.65	mm	Minimum Bare Conductor Diameter
ODS2			1.39	mm	Maximum Outside Diameter for Triple Insulated Wire

9 Performance Data

All measurements performed at room temperature, 60 Hz input frequency.

9.1 Full Load Efficiency

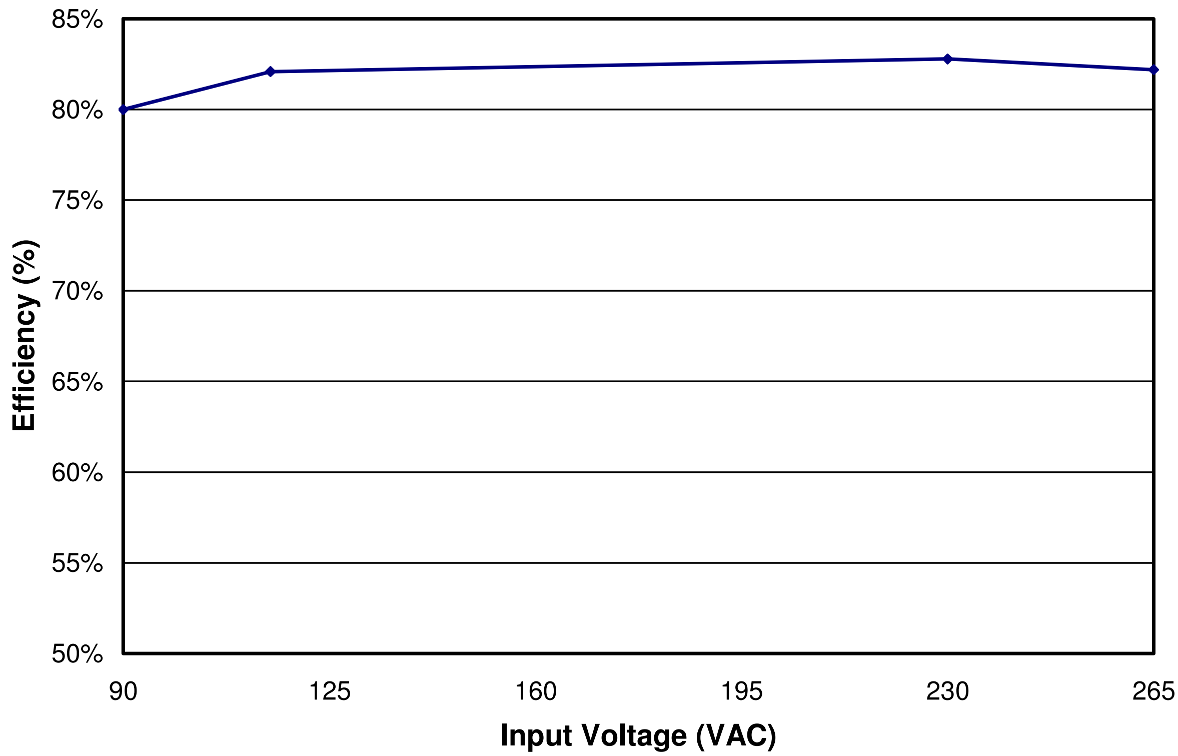

Figure 8 – Efficiency vs. Input Voltage, Room Temperature, 60 Hz.

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9.2 No-load Input Power

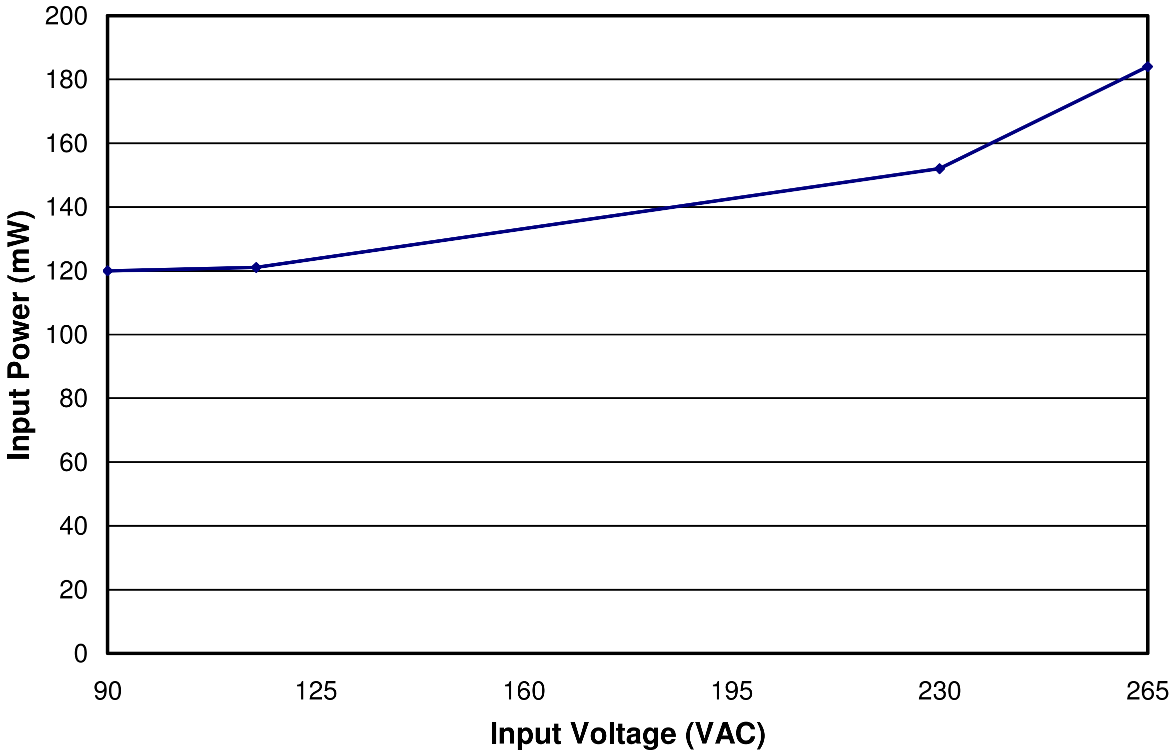

Figure 9 – Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.

9.3 Available Standby Output Power

The following chart shows the input power vs input voltage when 5 V has 50 mW load, 15 V has no load.

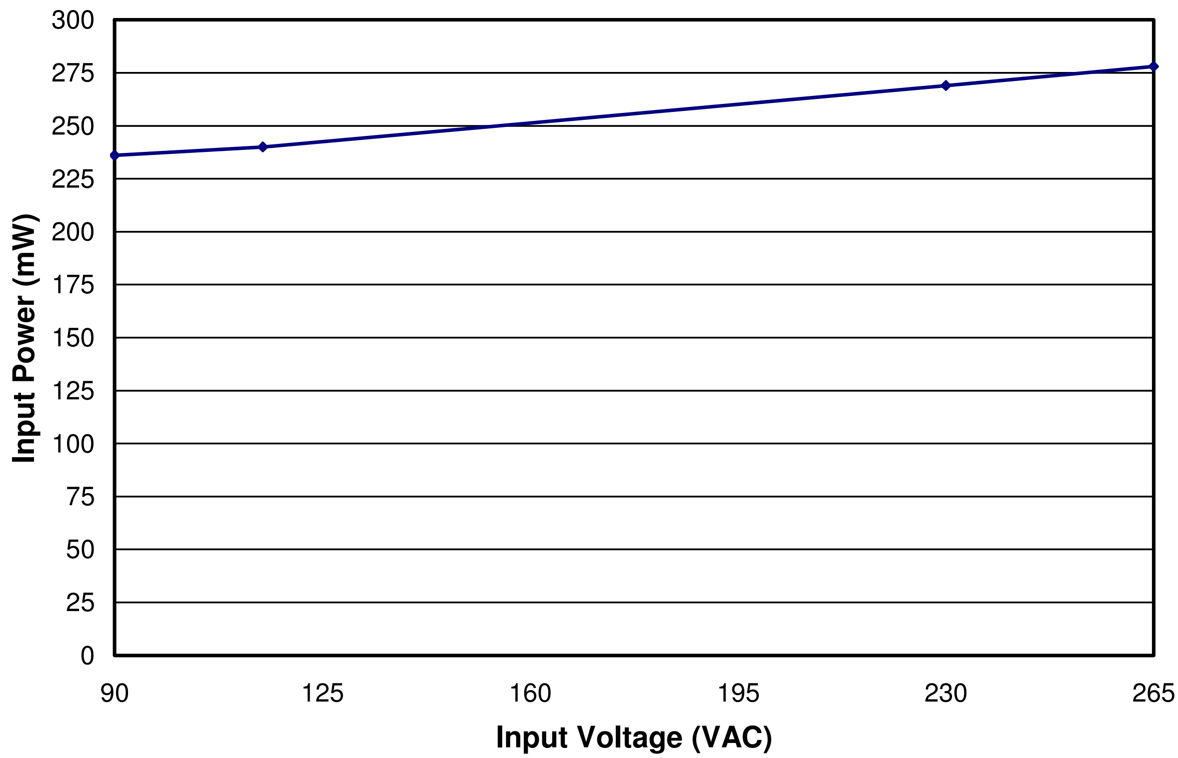

Figure 10 – Available Standby Power.

9.4 Regulation

9.4.1 Load

The following shows the 15 V regulation vs load and input voltage, when 5 V loaded 2.0 A.

15 V Load Current	Output Voltage (115 VAC Input)	Output Voltage (230 VAC Input)
0 A	17.89 V	17.91 V
2.0 A	14.6 V	14.54 V

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9.4.2 Line Regulation

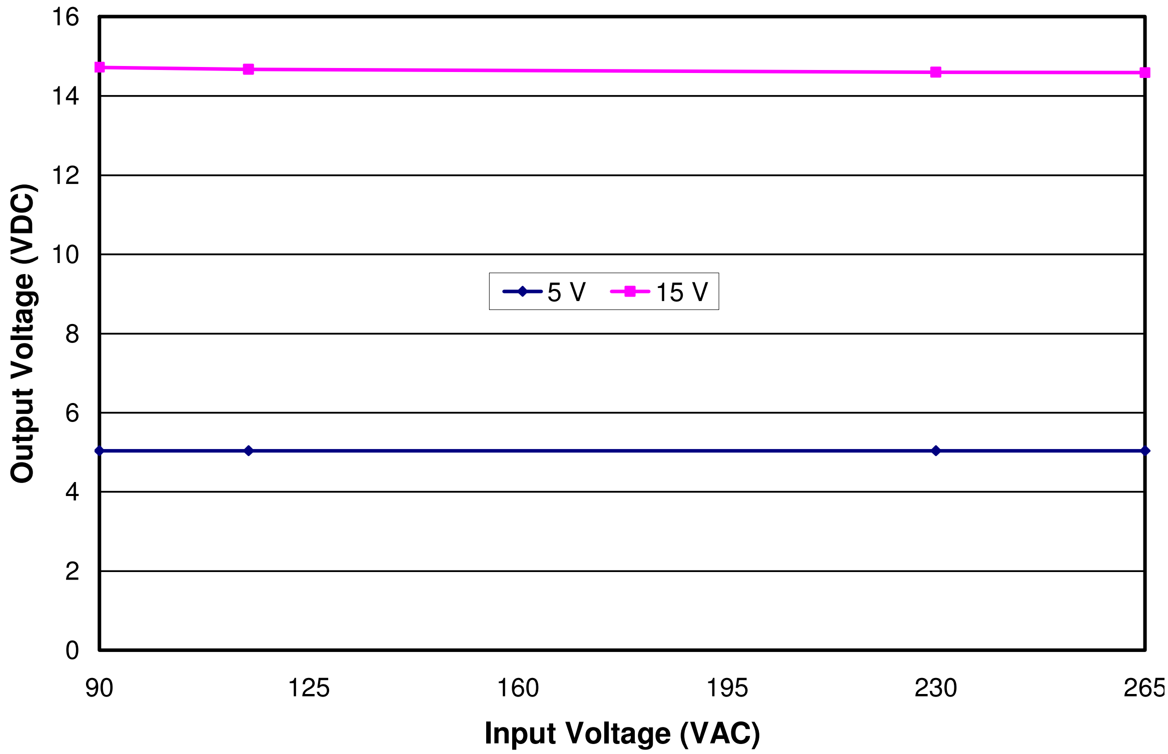

Figure 11 – Line Regulation, Room Temperature, Full Load.

9.5 Thermal Performance

The power supply was put in a completely covered box, to prevent air flow across the supply, and thermal measurements were taken. T-type thermo-couples were glued on to U1, T1, U1, D4, and D6. A thermo-couple for measuring ambient temperature was suspended in the box approximately one inch away from one side of the power supply. Figure 12 shows the test set-up.

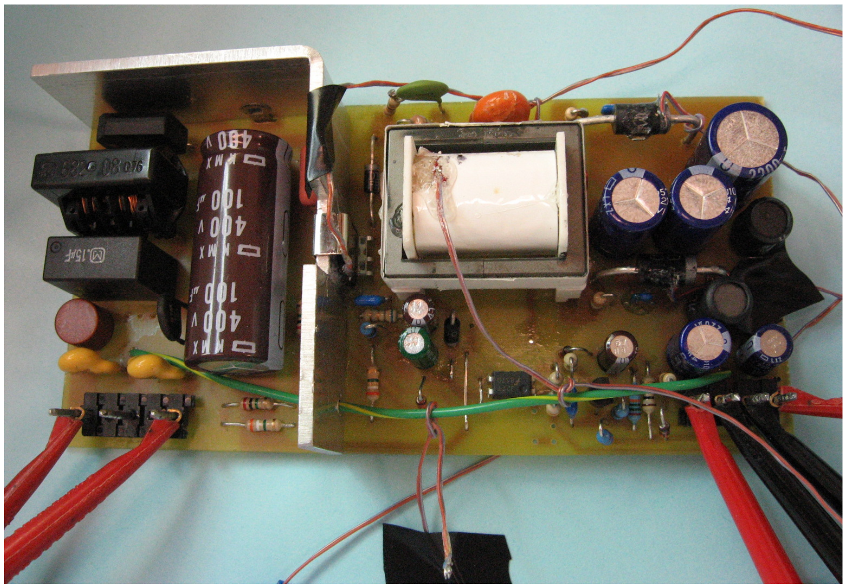

Figure 12 – Test Configuration for Taking Thermal Measurements.

Item	Temperature (°C)	
	90 VAC (50 Hz)	265 VAC
Ambient Temperature	49.1	50
T1	94.7	98.7
U1	87.7	76.8
D4	79.6	77.6
D6	98.8	93.9

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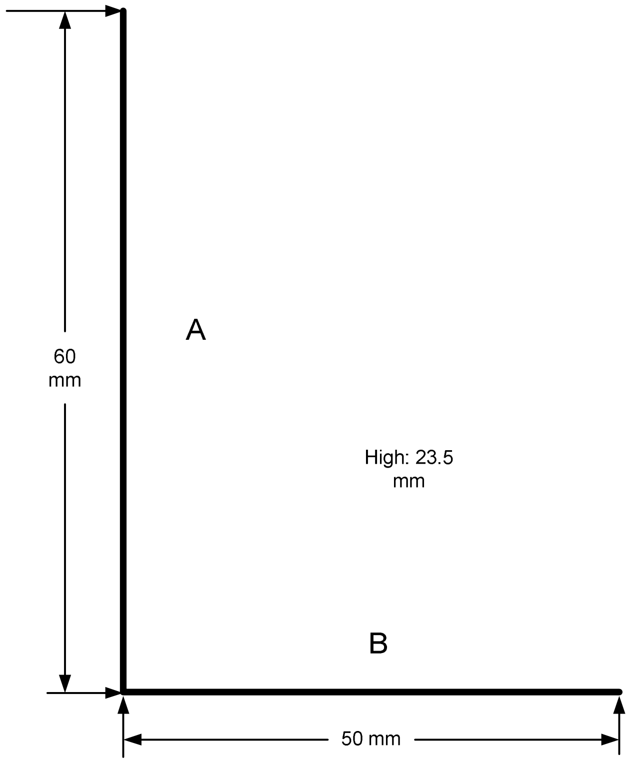
9.6 Thermal Effect of TOP256EN Heat Sink Size



Lowering the ambient temperature to 40 ºC allows the B section of the heat sink to be removed. The following table shows the measured results with a 90 VAC, 50 Hz input and 40 °C ambient temperature.

Item	Temperature (°C) 90 VAC (50Hz)
Ambient Temperature	40.7
T1	90.7
U1	91.8
D4	69.6
D10	95.4

9.6.1 Thermal Image

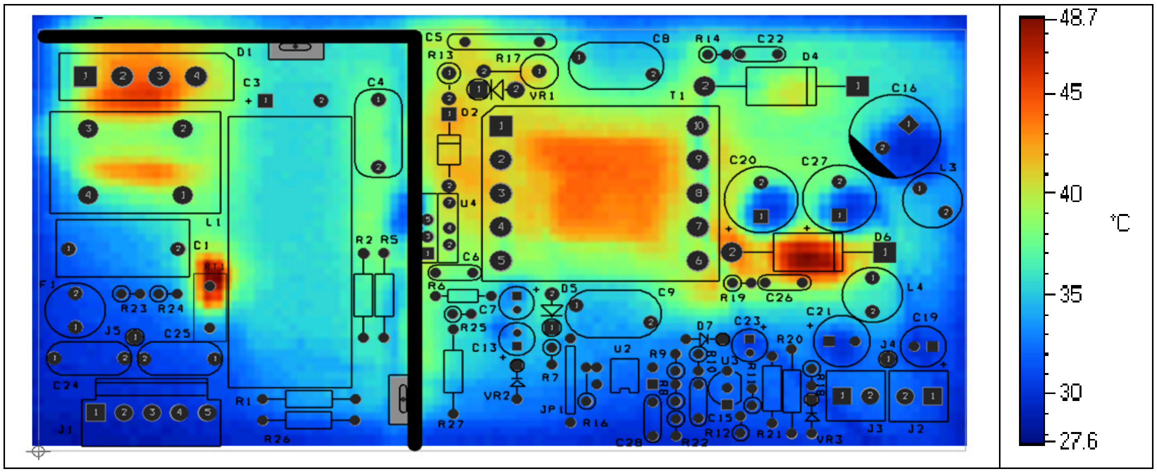


Figure 13 – Thermal Image with 90 VAC Input, Full Load. Test performed at room temperature (approximately 25 ºC) free convection environment.

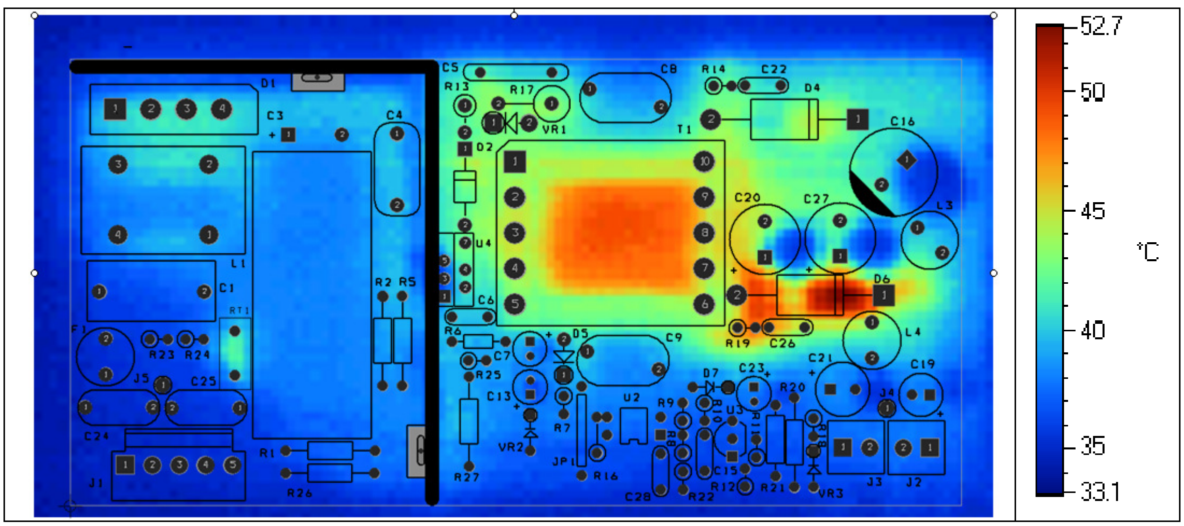


Figure 14 – Thermal Image with 265 VAC Input, Full Load. Test performed at room temperature (approximately 25 ºC) free convection environment.

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10 Waveforms

10.1 Drain Voltage

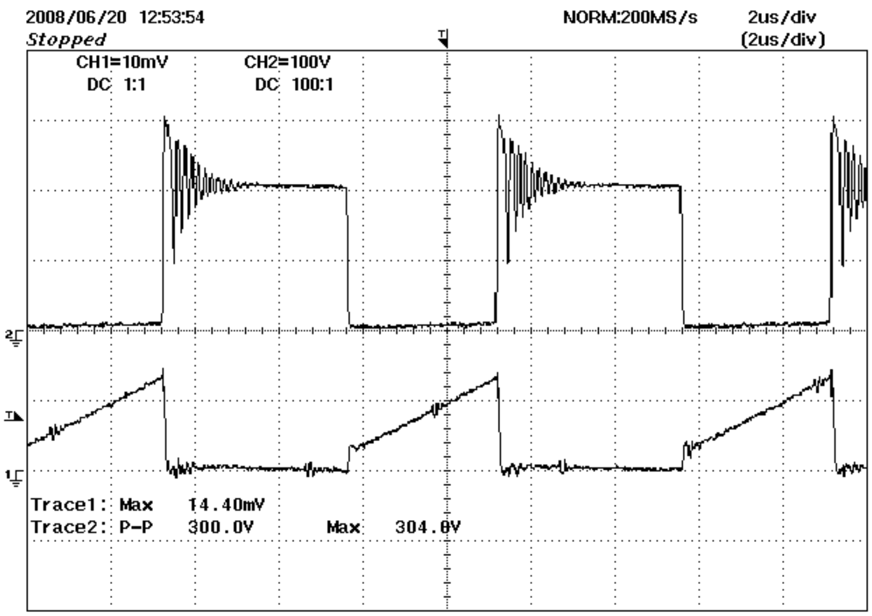

Figure 15 – Drain Voltage at 90 VAC, 2.0 A Load on Both 5 V and 15 V Outputs. Current: 1 A/div.

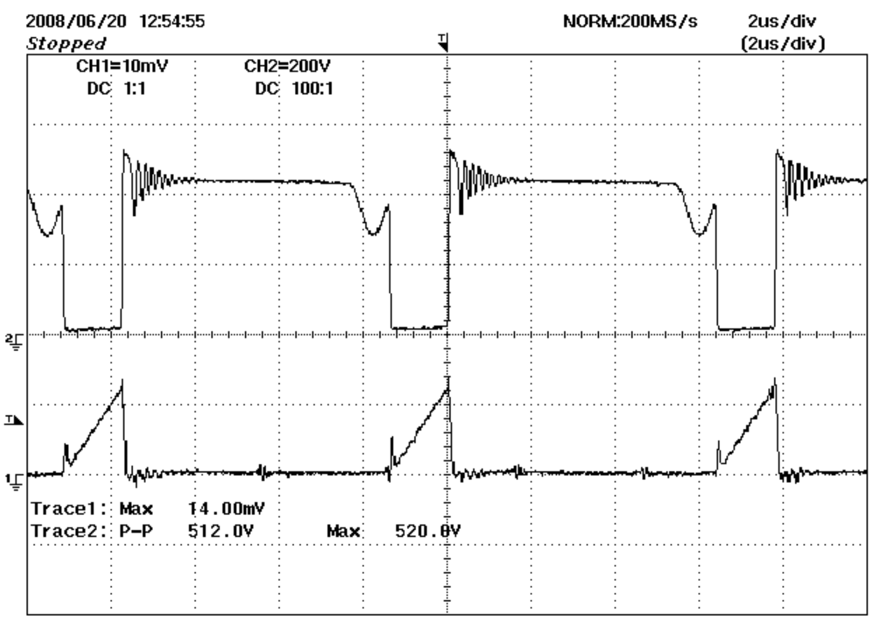

Figure 16 – Drain Voltage at 265 VAC Input, Full Load. Current: 1 A/div.

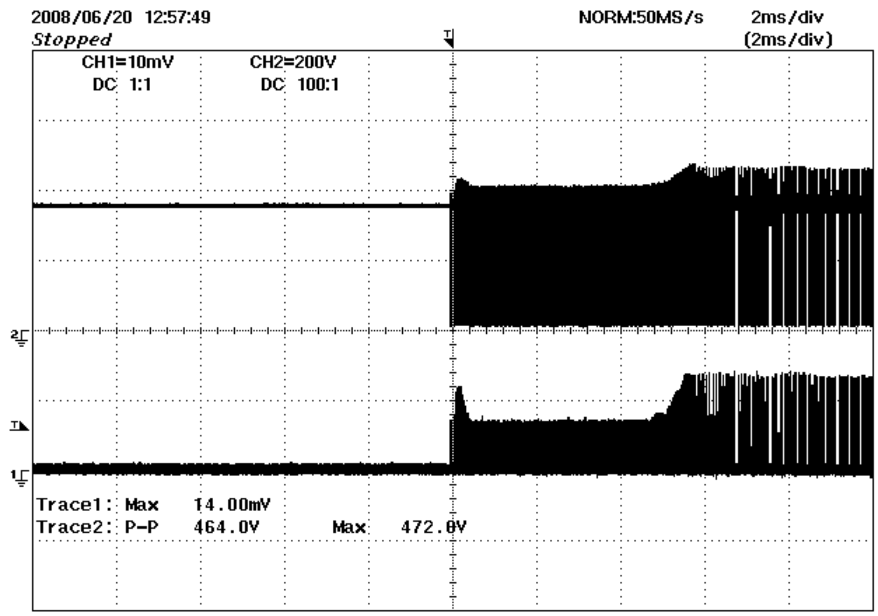

Figure 17 – Drain Voltage During Start-up at 265 VAC Input, Full Load. Current: 1 A/div.

10.2 Output Voltage Start-up Profile

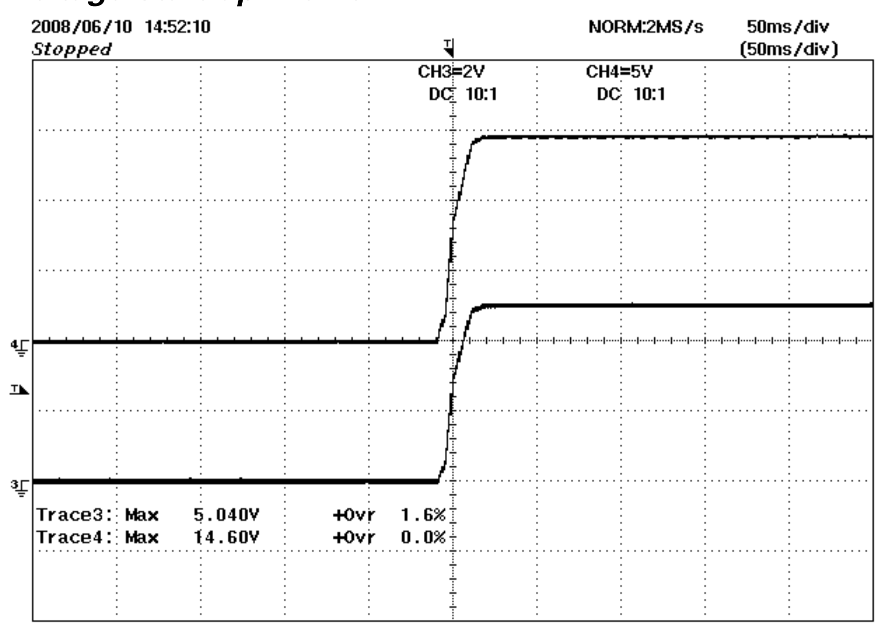

Figure 18 – Output Voltage at 115 VAC Input, During Start-up, Full Load.

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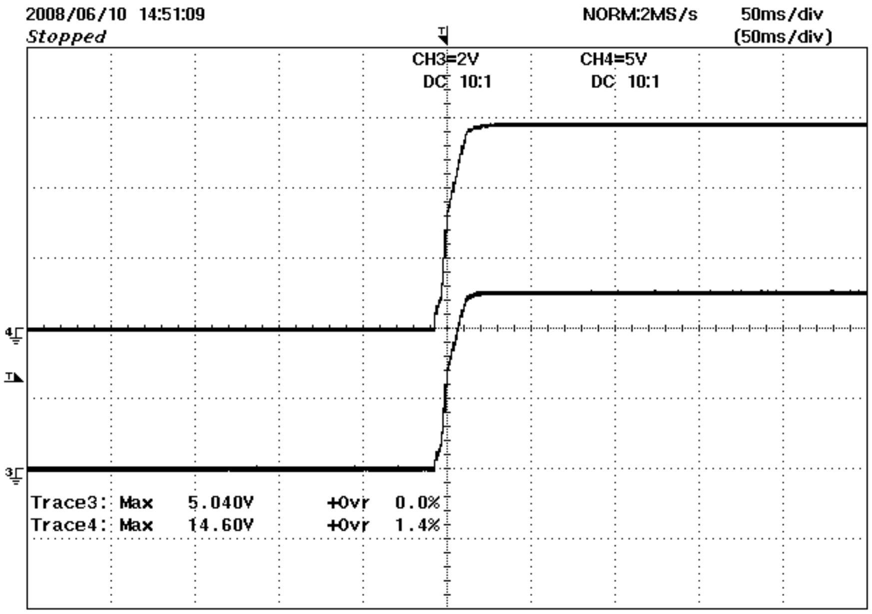

Figure 19 – Output Voltage at 230 VAC Input, During Start-up at Full Load.

10.3 Output Ripple Measurements

10.3.1 Ripple Measurement Technique

For DC output ripple measurements, use a modified oscilloscope test probe to reduce spurious signals. Details of the probe modification are provided in figures below.

Tie two capacitors in parallel across the probe tip of the 4987BA probe adapter. Use a 0.1 µF / 50 V ceramic type and 1.0 µF / 50 V aluminum electrolytic. The aluminum-electrolytic capacitor is polarized, so always maintain proper polarity across DC outputs.

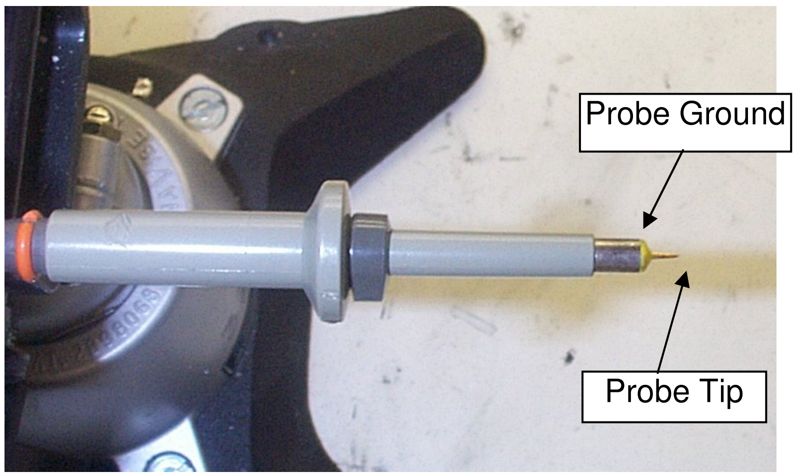

Figure 20 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

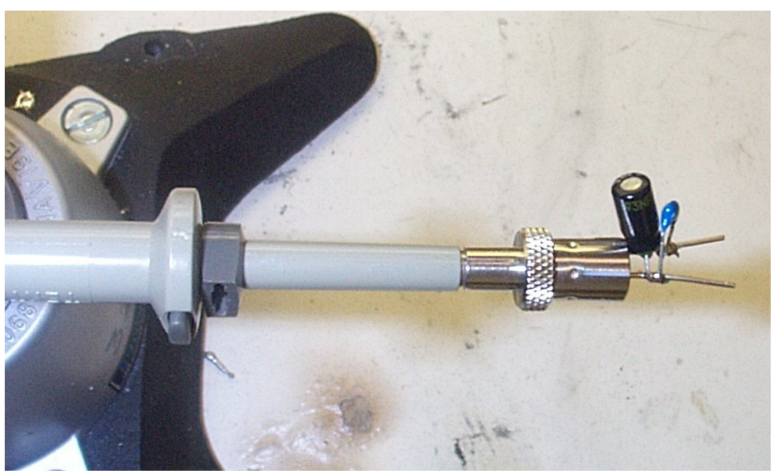

Figure 21 – Oscilloscope Probe with Probe Master (www.probemaster.com) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

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10.3.2 Measurement Results

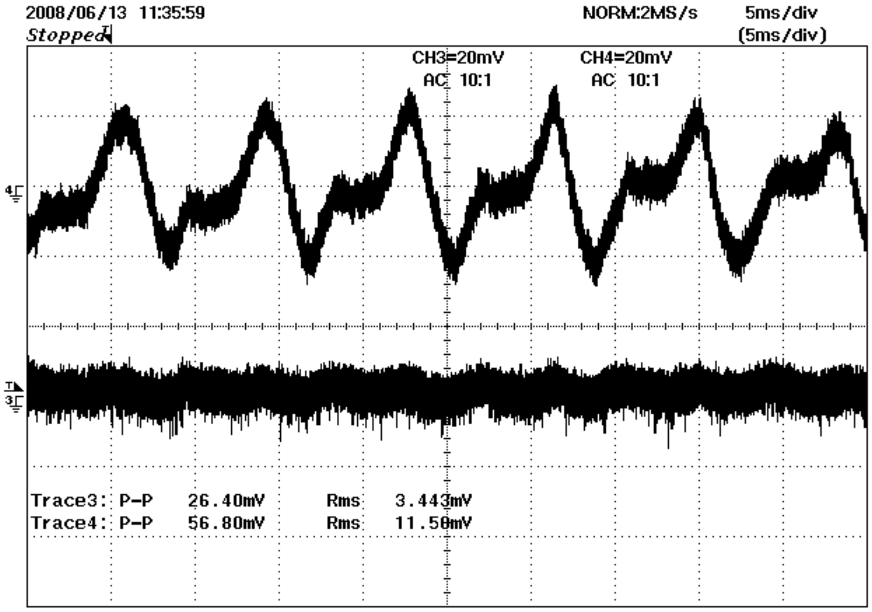

Figure 22 – Output Voltage Ripple and Noise at 115 VAC Input, Full Load.
Upper: 15 V Output, Lower: 5 V Output.

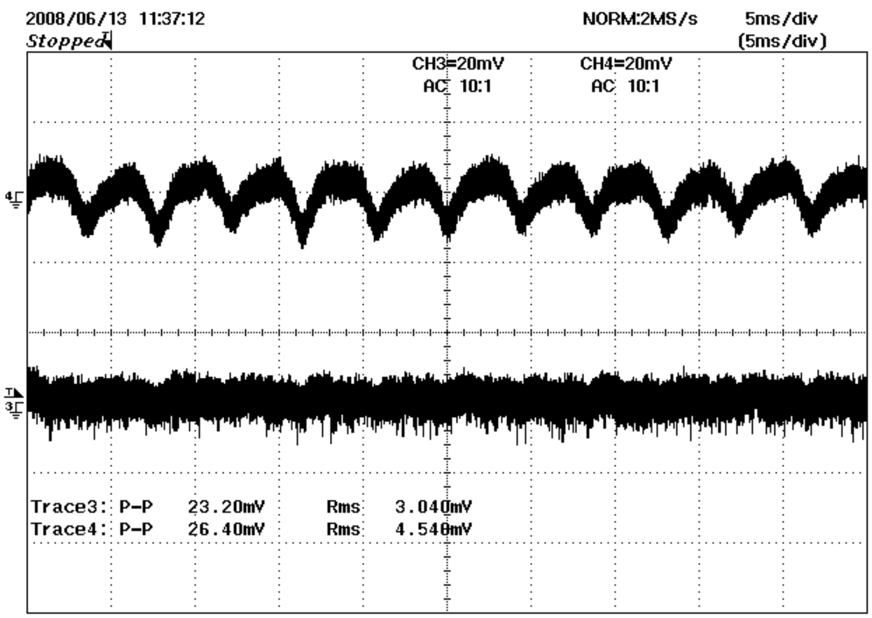

Figure 23 – Output Voltage Ripple and Noise at 230 VAC Input, Full Load.
Upper: 15 V Output, Lower: 5 V Output.

11 Control Loop Analysis

11.1 Gain and Phase at 90 VAC Input

The following gain and phase measurements were taken at 90 VAC input, full load. Figure 24 shows a phase margin of approximately 70º, and a gain margin in excess of 10 dB. The crossover frequency is approximately 1 kHz.

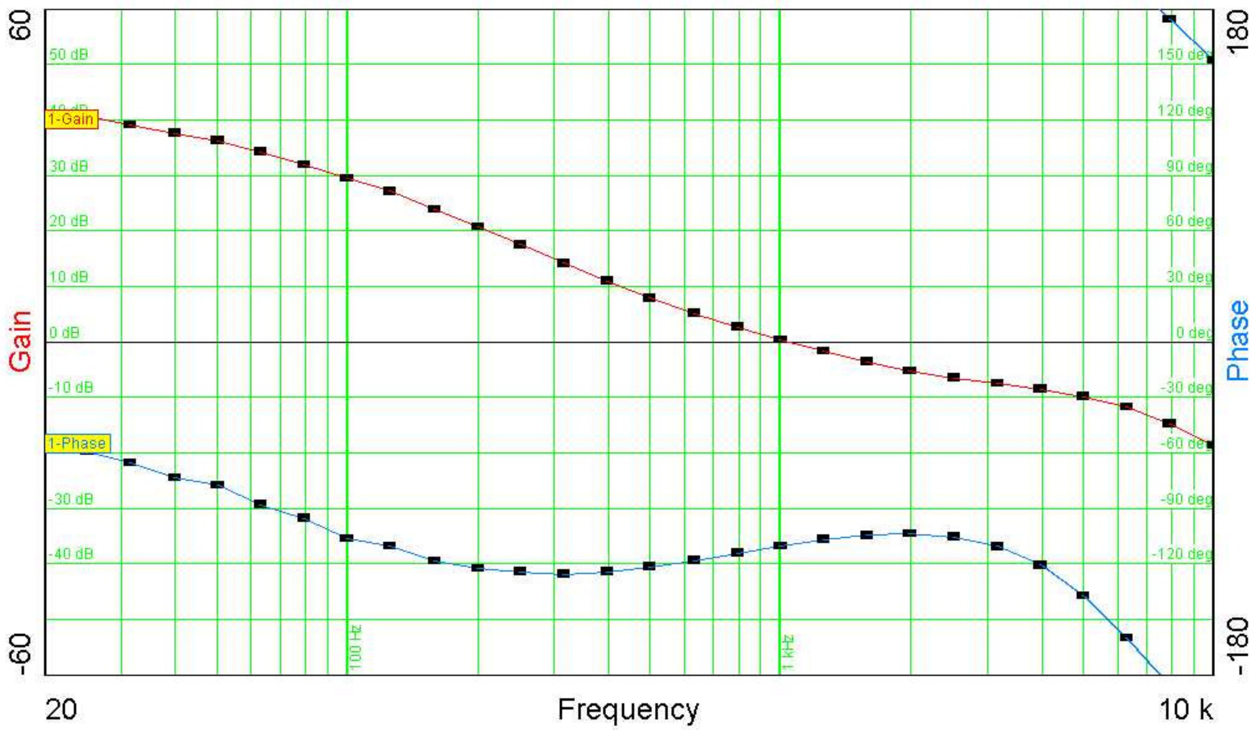

Figure 24 – Gain and Phase Plots at 90 VAC, Full Load.

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11.2 Gain and Phase at 230 VAC Input

The following gain and phase measurements were taken at 265 VAC input, full load. Figure 25 shows a phase margin of approximately 95º and a gain margin in excess of 15 dB. The crossover frequency is approximately 1.3 kHz.

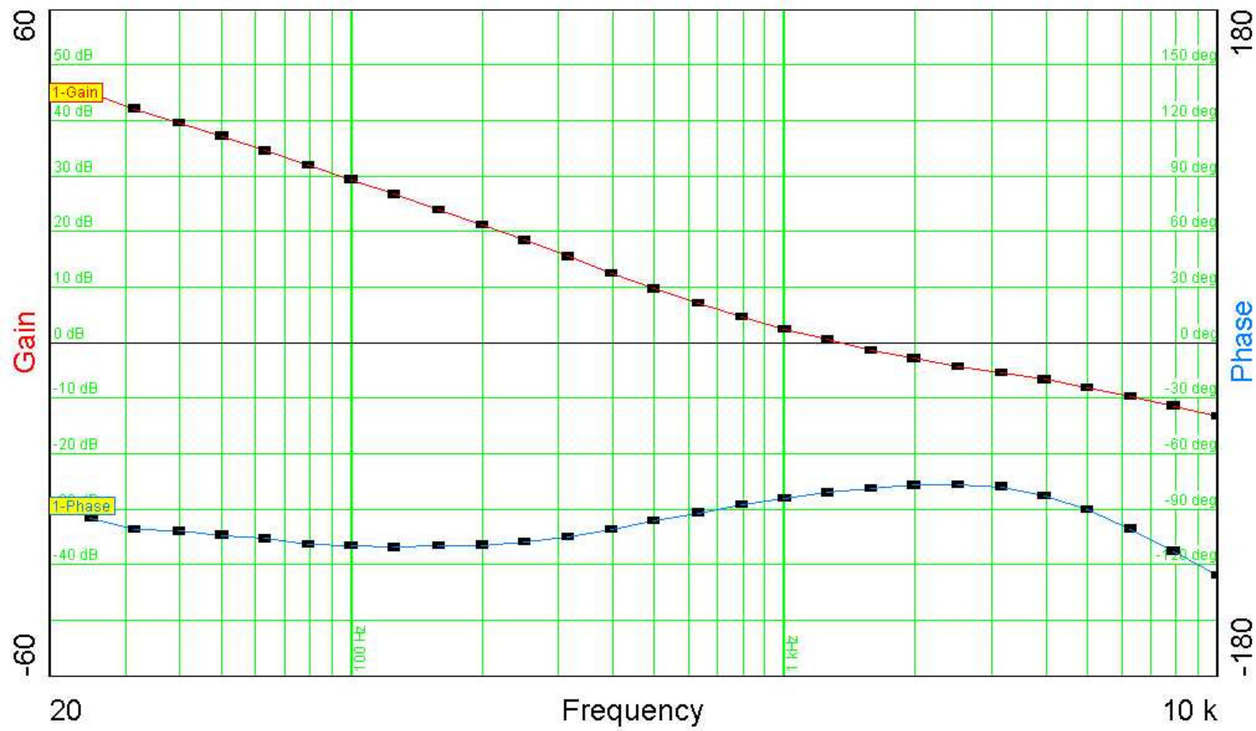

Figure 25 – Gain and Phase Plots at 265 VAC Input, Full Load.

12 Conducted EMI

Conducted EMI measurements were taken with the supply output connected to the LISN earth ground.

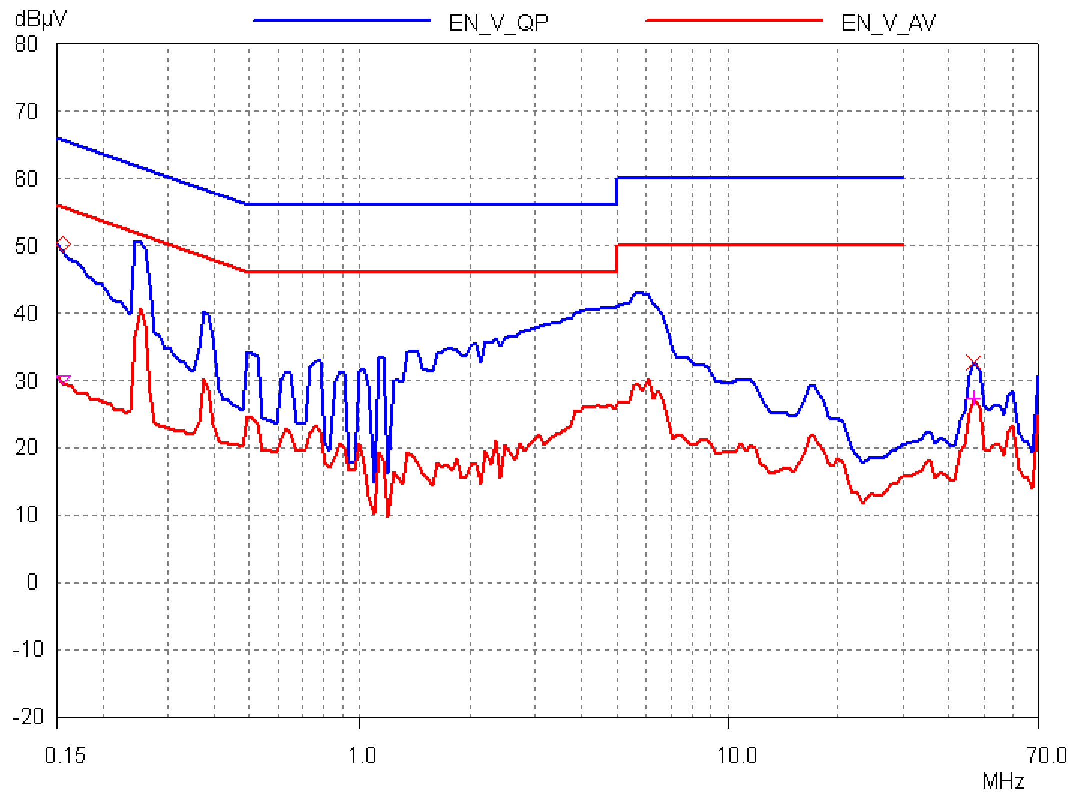

Figure 26 – Conducted EMI, Maximum Steady-state Load, 115 VAC, 60 Hz, EN55022 B Limits.

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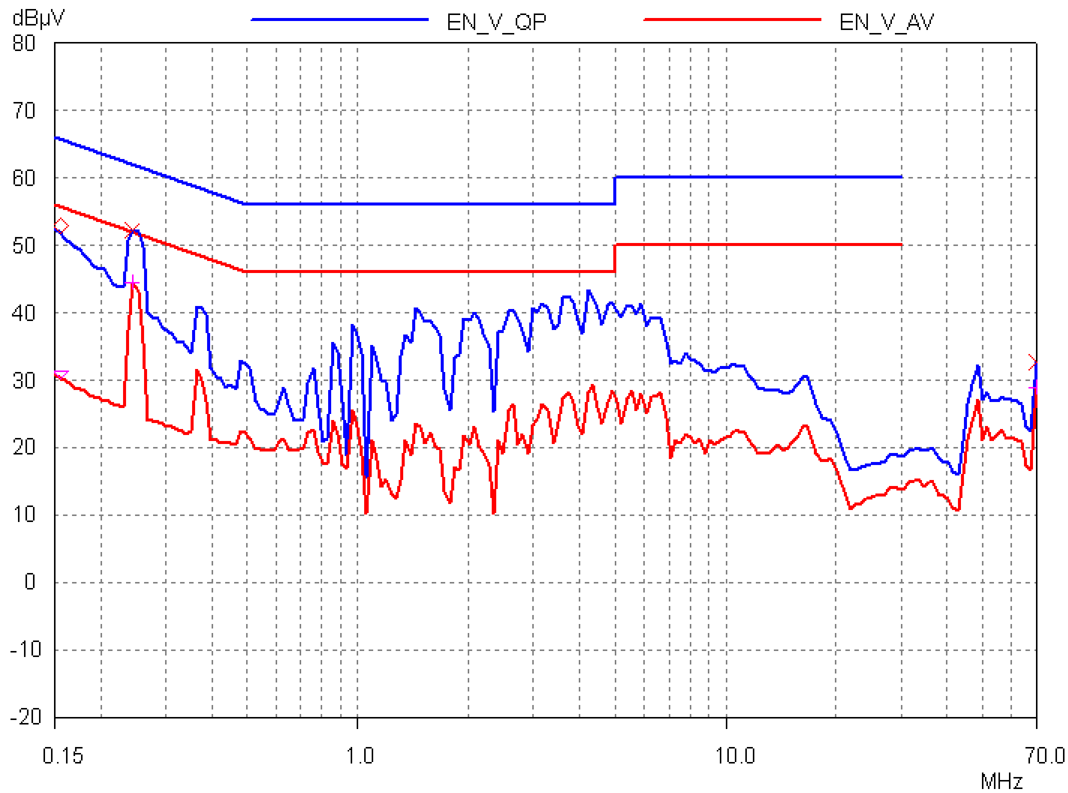

Figure 27 – Conducted EMI, Maximum Steady-state Load, 230 VAC, 60 Hz, EN55022 B Limits.

13 Revision History

Date	Author	Revision	Description & changes	Reviewed
13-Oct-08	JD	1.0	Initial Release	SGK

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